ADVANCED SEALS AT GE RESEARCH AND DEVELOPMENT CENTER

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Objective of CRD Seals Team is to develop advanced seals for turbomachinery applications

Presentation Overview - Who are the members, What seals we are developing, Where they are being applied, and What testing capabilities we have at CRD

CRD Seals Team Members - There is some flux in and out of the team; there are generally around 8 full time team members at any given time.

Advanced Seals
at GE - Research & Development Center

Seal Types

Static Seals

- Cloth Seals
- Piston Rings

Dynamic Seals

- Brush Seals
- Aspirating Seals
- Labyrinth Seals
- Honeycomb Seals
- Abradable Seals

Testing Capability

Static Seal Testing
Brush & Cloth Seals
1000 psi
1000F

36”/50” Dynamic Seal Testing
Brush, Aspirating, HC Seals
36 & 50 in. Dia.
800 ft/sec
120 psi
100 F

5” Dynamic Seal Testing
Brush, Labyrinth Seals
1200 psi
1000 F
Air & Steam
800 ft/sec

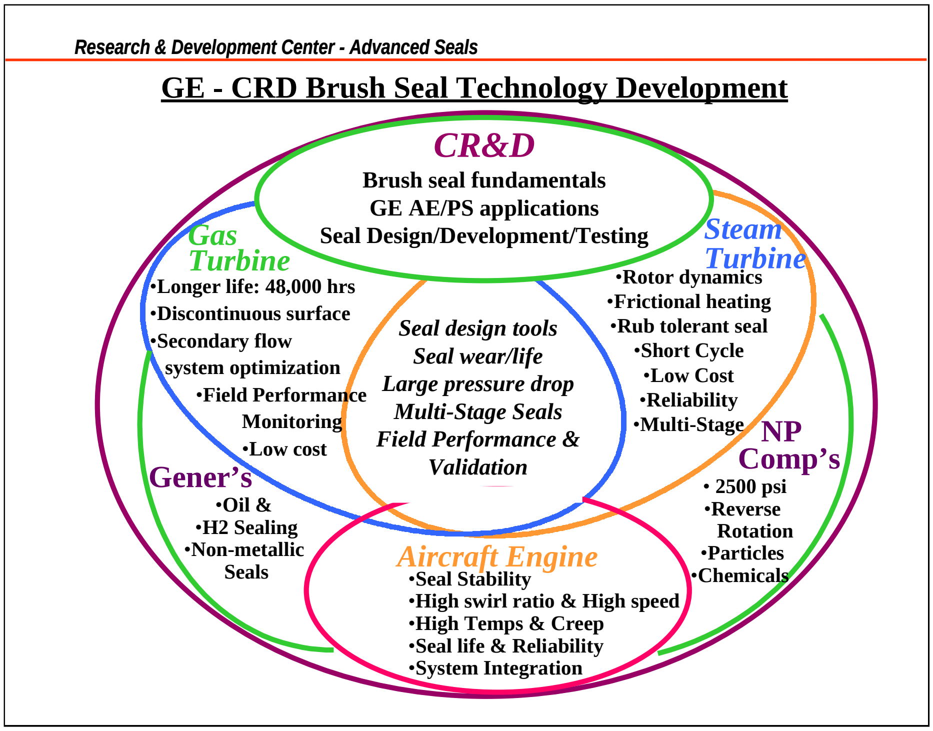
Applications

- Gas Turbines
  - Compressor &
  - Turbine Seals
- Steam Turbines
- Generators
- Compressors
- Aircraft Engines

Types of Seals being developed at GE CRD (Static and Dynamic).

Summary of Test Rigs at CRD and their capabilities (Shoebox, 36”, 5.1”).

Areas of Application for CRD-Developed Advanced Seals (GT, ST, Generators, Compressors, AE’s)



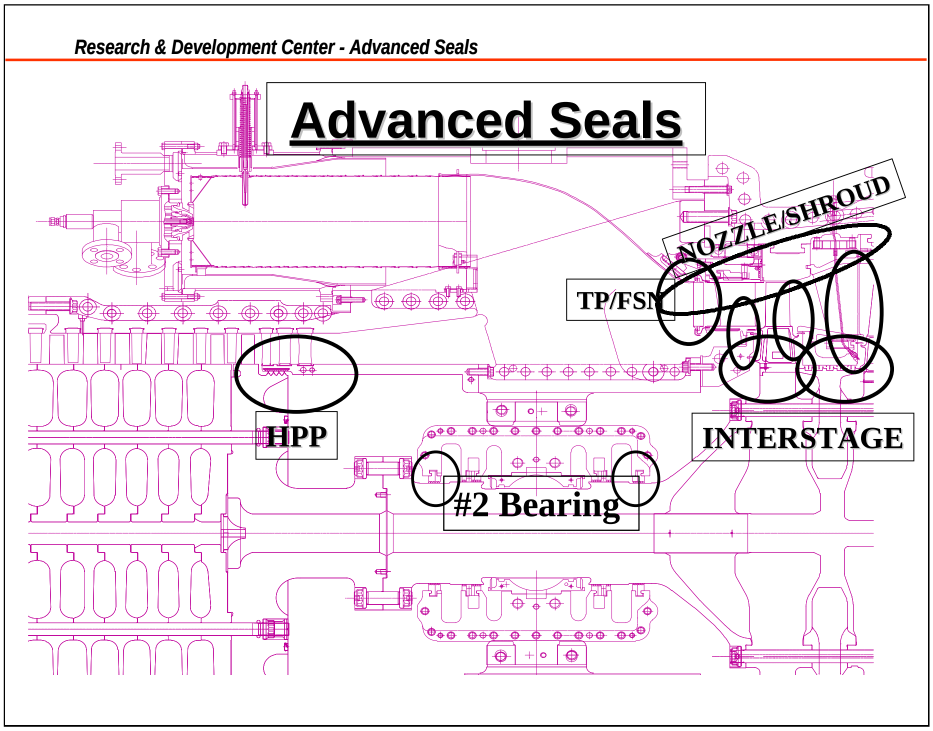
Synergy Chart

CRD develops seal fundamentals/design tools that are shared across GE businesses.

Many seal applications share common design challenges (where areas overlap).

Each application also has its own unique challenges.

CRD uses analytical tools (FEA, CFD, fundamental equations, statistical methods, etc.) as well as test data to develop Transfer Functions that can be used to design brush seals for new applications.



Example of areas where CRD-Developed Advanced Seals are being applied.

7EA GT has brush seals at HPP, #2 Bearing, and Interstage locations;

Cloth seals at Transition Piece/First Stage Nozzle (TP/FSN) and Nozzle Shroud locations.

Advanced Seal Test Rigs at CRD

	"Shoebox" Rig	5.1" Rotary Rig	36" Rotary Rig
Working Fluid	Air	Air or Steam	Air
Total Flow Rate (lbm/s)	2.0	1.5 Steam/2.0 Air	12
Inlet Pressure (psig)	430	1200 Steam/450 Air	125
Exhaust Pressure (psig)	430	300	125
Temperature (°F)	1000*	750 Steam/1000 Air*	100
Speed (RPM)	N/A	36000	2400
Surface Speed (ft/s)	N/A	800	375
Axial Motion (in.)	N/A	+/- 0.75	N/A
Seal Configuration	12" max. linear strip (1 seal strip)	5.1" diameter brush, labyrinth, etc. (2 seals req'd)	36" dia. brush, aspirating, etc. (2 seals req'd)

Note: Temperature limits depend on test pressures. Limits given are ablsolute maximum.

Advanced seal testing capabilities at CRD

3 test rigs:

"Shoebox" (Static testing, Air only)

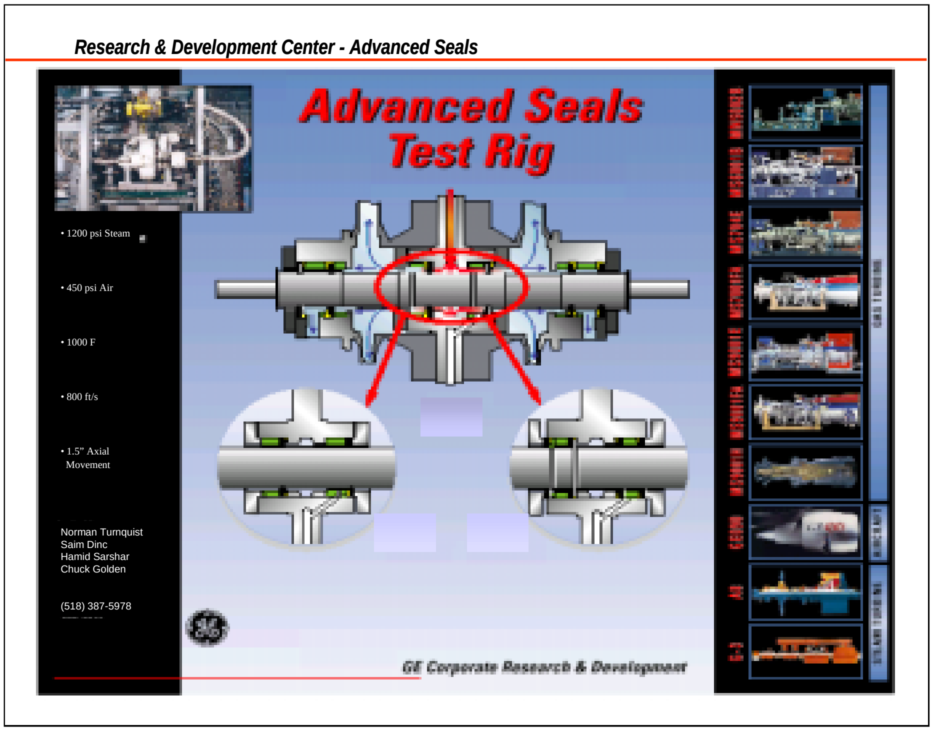
Used for static seal characterization and basic leakage testing of labyrinth, honeycomb, and brush seals.

5.1" Rotary Rig (Dynamic testing, Air or Steam, up to 1200 psia)

Used for testing subscale seals at approximately full scale conditions (speed, pressure, temperature)

36" Rotary Rig (can be reconfigured to 50") (Dynamic testing, Air only)

Used for testing full scale seals at subscale conditions.



CRD 5.1" Rotary Seals Test Rig

Used for dynamic leakage testing of labyrinth and brush seals.

Used for static leakage testing of piston rings, thermal rings.

Capable of testing in Air or Steam.

1200 psia maximum upstream pressure; can be backpressured to 300 psia.

Up to 800 ft/s surface speed.

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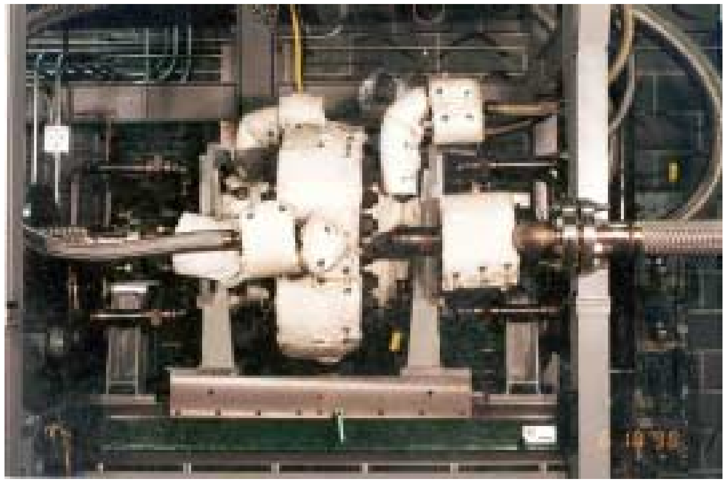
GE CRD 5.1” Seals Test Rig



Side view of the CRD 5.1” Rotary Seals Test Rig

Air or Steam enters through center ring.

Flow splits between two sets of test seals.

Independent control of inlet and both exhaust pressures.

Pressure vessel mounted on slider for axial movement (for hysteresis testing).

Rig is used for leakage, wear, and hysteresis testing.

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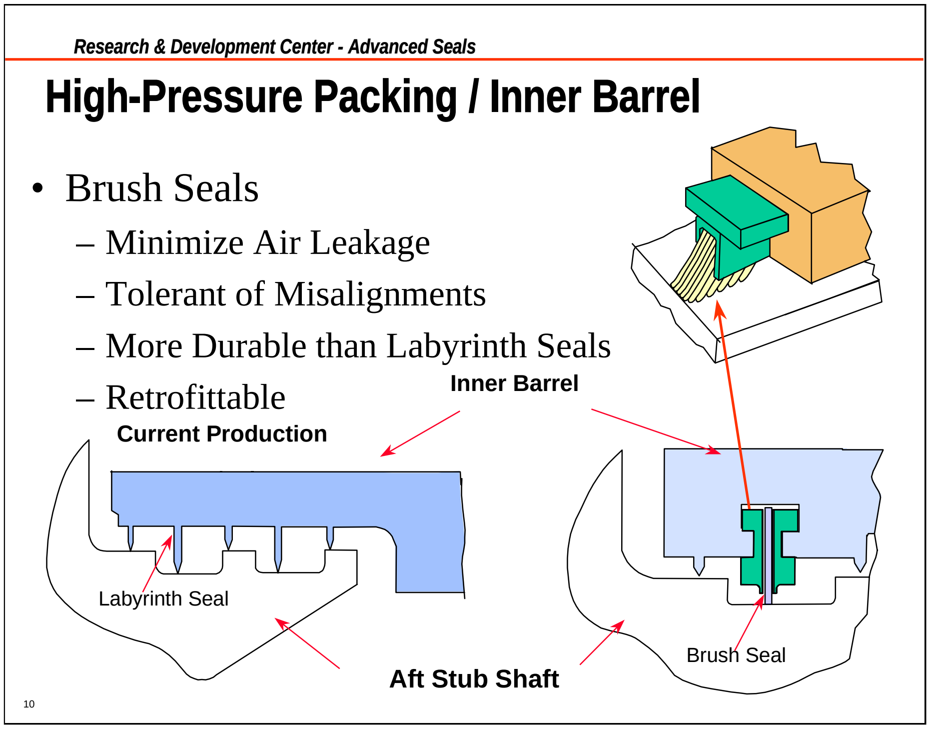
GE CRD 5.1” Seals Test Rig

End view of CRD 5.1” Rotary Seals Test Rig

Solid shaft mounted on hydrodynamic bearings.

Variable-speed rotor up to 36,000 RPM.

Bentley-Nevada vibration data acquisition system to study seals’ effect on rotor dynamics.



- The seal between the Compressor Discharge Casing Inner Barrel and the compressor Aft Stub Shaft is known as the High-Pressure Packing.
- The HPP regulates flow of compressor discharge air between the stationary inner barrel and the compressor rotor aft stub shaft into the first forward wheel space.
- With conventional labyrinth tooth/land seal packings, the minimum clearance that can be tolerated is dictated by expected rotor displacements during transients, differential thermal growth, and by wheel space cooling requirements.
- When rubs do occur, labyrinth teeth can be damaged, which can result in excessive leakage through the packing. A 20 mil rub (not uncommon) translates into a loss in performance of up to 1%.
- The new brush seal replaces one of the existing labyrinth tooth/land seal with a rub tolerant brush seal element.
- HPP Brush seals consist of a pack of fine wires held in a frame mounted on the inner barrel. The inherent flexibility of the brush seal material allows it to bend under transient conditions which would damage the standard design labyrinth packing. The sealing efficiency of a single brush is approximately 10 times that of a labyrinth seal under similar conditions.
- Brush seals offer better than new performance and will enable the unit to sustain initial performance levels over extended periods of time because the inevitable rubs will not increase the leakage past the seals.

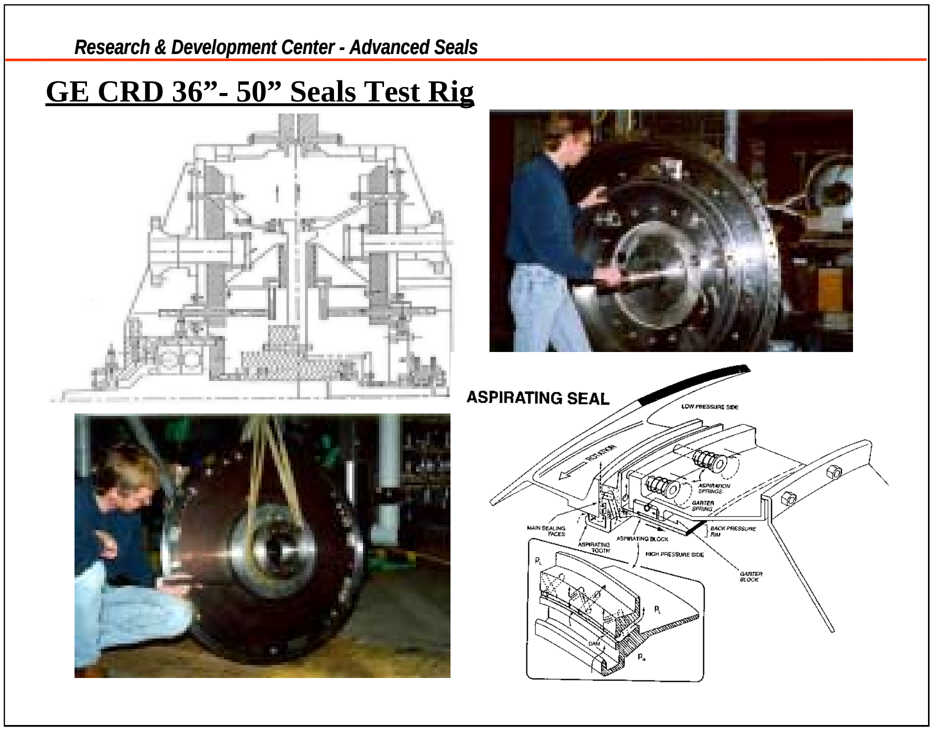
Example of a GT brush seal in the field

7EA HPP Brush Seal after 21,000 hours of service.

Minimal seal and rotor wear observed.

Seal was reinstalled for an additional 24,000 hours.

Commercial offering; GE has hundreds of these seals currently in service.



CRD 36”/50” Rotary Seals Test Rig in 36” Aspirating Seal configuration

Cross section of the rig showing disk with Aspirating Seal on left side and Brush seal on right side.

In this configuration, air enters rig from both sides and exhausts through center plenum.

Both inlet pressures and the exhaust pressure are controlled independently.

Top right photograph shows pivot location (near 12:00 position) for tilt mechanism to simulate angular misalignment of seal to rotor.

Test results from Aspirating Seal development program presented at 1997, 1998, and 1999 NASA Seals Workshops by N.A. Turnquist.

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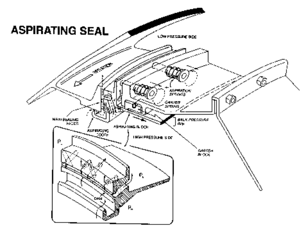
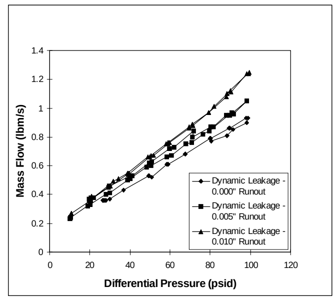
Aspirating Face Seal



Features:
-All-metal construction (410SS)
- Non-contacting
- Hydrostatic gas bearing when closed
- Single tooth labyrinth when retracted
- Operates at 0.0015”-0.003” film thickness



36” Prototype Seal Testing at CRD:
- Tested up to 100 psid, 2400 RPM in Ambient Temp. Air
- Tested with rotor axial TIR of 0, 5, and 10 mils
- Tested with up to 0.27 degrees of angular misalignment

The aspirating seal shows promise as a potential replacement for labyrinth seals in aircraft engines.

Features of the 36” Aspirating Seal listed on top right of slide

Tests results show good leakage behavior even with 0.005” and 0.010” TIR of axial rotor run out (wobble), as shown by graph.

Seal tested in the 36” Rotary Rig up to 100 psid, 2400 RPM, with up to 0.010” rotor TIR and 0.27 degrees of angular seal/rotor misalignment.

Seal will be tested in a GE90 engine (ground test) in 2001 (Tom Tseng presenting on this topic).

New CRD Abradable Rub Rig

Rig and dedicated computer data acquisition system during operation

Rig with cover open--sample is mounted below rotor and moves vertically

Rig variables:
- •Max. blade surface speed
- •Max. shroud surface temperature
- •Incursion rate
- •Incursion depth

Parameter measured:
- •Shroud location vs. time
- •Shroud X & Y accelerations vs. time
- •Backside temperature vs. time (via. T/C)
- •Relative blade vs. shroud wear depth
- •Surface conditions before/after rub

GE CRD's new Abradable Rub Rig

Rig being used to evaluate Abradable Seal materials/designs for various engine and turbomachinery applications.

Rig is currently located off-site; will be moved to CRD by end of 2000.